



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

A SURVEY OF THE HAWAIIAN CORAL REEFS

VAUGHAN MacCAUGHEY

PROFESSOR OF BOTANY, COLLEGE OF HAWAII, HONOLULU, HAWAII

DURING a residence of nearly ten years in the Hawaiian Archipelago the writer has had opportunity of visiting and exploring many of the coral reefs, and has been much interested in their formation, flora, and fauna. The present paper aims to present the salient and significant facts relating to the natural history of these remarkable reefs, in compact and largely non-technical form. There is a large scattered literature (inaccessible to the average reader), dealing with the coral reefs and their life, but the writer believes this to be the first time that the following data have appeared within the confines of a single paper.

The Hawaiian Archipelago is situated in the midst of the North Pacific Ocean. It lies between latitudes $18^{\circ} 54'$ and $22^{\circ} 14'$ and $154^{\circ} 48'$ and $160^{\circ} 13'$ West Longitude, being about 2,020 miles southwest of San Francisco. Its east and west extension is nearly two thousand miles. the islands are but the apices of a titanic mountain range that rises to heights of from three to five miles from the floor of the ocean.

This long archipelago, comprising about twenty-two islands, is remarkable for the simplicity of its geologic formations. Only two classes of rock material are known in the entire group—lava and coral. There are numerous subdivisions of these groups (for example, there are many varieties of lava), but all the known rock-formations give conclusive evidence of having originated from either one of two sources—volcanic or coralline. It is extremely interesting to consider that all of these islands are compounded of two such diverse elements—one from a roaring lake of incandescent lava; the other from the age-long

labors of coral polyps. A strange "partnership," without parallel in the annals of natural history.

The islands of the Hawaiian group may be classified on this basis. The large, high islands of the eastern portion of the archipelago are composed almost wholly of lava, with small fringing reefs. The low, small islets that comprise the western extension of the archipelago are made almost wholly of coral, that is, in so far as their exposed portions are concerned. The coral formations undoubtedly rest upon a volcanic substratum. The grouping may be expressed as follows:

- I. Large mountainous lava islands, forming a compact group at eastern end of archipelago; elevations over 1,000 ft.
 - A. With well-developed fringing reef:
Niihau, 1,300 ft.; Kauai, 5,250 ft.
Oahu, 4,040 ft.
Molokai, 4,958 ft.; Lanai, 3,400 ft.; Kahoolawe, 1,472 ft.
 - B. With scanty fringing reef:
Hawaii, 13,825 ft.; Maui, 10,032 ft.
- II. Small, low islets, scattered along the western axis of the archipelago; elevations below 1,000 ft.
 - C. Eroded volcanic blocks, 120-900 ft., with fringing coral reef: Nihoa, French Frigates Shoals, Gardner I.
 - D. Elevated coral islands, 45-55 ft., with fringing reef: Laysan, Lisianski.
 - E. Typical coral atolls: Pearl-and-Hermes, Midway, Ocean.
 - D. Reefs with visible surf, but no exposed coral: Maro Reef, Dowsett's Reef.

The entire series, named in sequence from east to west, is: Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, Niihau, Nihoa, Necker, French Frigates Shoal, Gardner, Dowsett's Reef, Maro Reef, Laysan, Lisianski, Pearl-and-Hermes, Midway, Ocean. The two extremes—Hawaii and Ocean Island—present a contrast of wonder-

ful vividness. Mauna Loa, the greatest active volcano on the planet, dominates the island of Hawaii. Its colossal dome is crowned by a summit lake of reverberating liquid lava, with spectacular displays of high-jetting fire fountains. The bulk of the island is still growing, through intermittent outpourings of lava. Ocean Island, on the other hand, is the last white fragment of a subsiding coral-crowned mountain—perhaps a dead volcano, that may have resembled Loa in many respects, but which has been drawn inexorably into the abysses of the Pacific. One represents the culmination of the volcanic forces; the other the climax of coral work—an atoll on a tropic sea.

Of the larger eastward islands, Kauai and Oahu are of particular interest, as they have the largest coral reefs, and support the most luxuriant marine life. The reefs are all of the fringing or platform type, and vary in width from a few hundred feet to half a mile. Reefs are well developed along the southern or leeward shores of the two islands mentioned, and also, to a lesser degree, along the northern coasts. Oahu is almost encircled by coral reefs, whereas Kauai, Molokai, and Maui have numerous coastal stretches wholly free from coral. The little island of Niihau, to the west of Kauai, has considerable coral reef.

It is significant to note that although the majority of corals, particularly the more massive reef-building forms, occur only in the shallow waters of tropic seas, there are a number of species that inhabit deep, cold waters. *Lophohelia prolifera* and *Dendrophyllia ramea*, for example, form dense beds at depths of from 600 to 1,200 ft. off the coasts of Norway, Scotland, and Portugal. The general requirement, however, is shallow water whose mean temperature does not fall below 68° F., and the reef-building species do not flourish unless the temperature is considerably higher. Although a single Hawaiian species of mushroom-like coral (*Bathyactes Hawaiiensis*) was dredged by the *Albatross* from a depth of nearly 7,000 ft., most of the Hawaiian forms live in waters of

6–150 ft. depth. Of the 34 Hawaiian genera, 14 habituate this shallow-water zone throughout the archipelago, and 10 of these occur on the leeward reefs of Oahu between Leahi and Pearl Harbor.

Dana's¹ comprehensive statement concerning the reef-building corals may be compactly summarized. He states that it is important to have a correct apprehension of what are those reef species as distinct from those of colder and deeper seas. The coral-reef species of corals are the following:

1. In the *Astræa* tribe, all the many known species.
 2. In the *Fungia* tribe, almost all the known species.
 3. In the *Oculina* tribe, all of the *Orbicellids*; part of the *Oculinids* and *Stylasterids*; some of the *Caryophyllids*, *Astrangids*, and *Stylophorids*; all of the *Pocilloporids*.
 4. In the *Madrepora* tribe, all of the *Madreporids* and *Poritids*; many of the *Dendrophyllia* family.
 5. Among *Alcyonoids*, numerous species of the *Alcyonium* and *Gorgonia* tribes and some of the *Pennatulacea*.
 6. Among *Hydroids*, the *Millepores* and *Heliopores*.
 7. Among Algæ, many *Nullipores* and *Corallines*.
- He further states that

Through the *torrid* region, in the central and western Pacific, that is, within 15° to 18° of the equator, where the temperature of the surface is never below 74° F. for any month of the year, all the prominent genera of reef-forming species are abundantly represented. The Hawaiian Islands . . . are outside of the torrid zone of oceanic temperature, in the *subtorrid*, and the corals are consequently less luxuriant and much fewer in species. There are no *Madrepores*, and but few of the *Astræa* and *Fungia* tribes; while there is a profusion of the corals of the hardier genera, *Porites* and *Pocilliporæ*.

The more abundant reef builders, at moderate depths, are the madreporcs, astræids, porites and meandrines. At depths of 90–120 ft. the millepores and seriatopores predominate. The great field of coral development thus lies between low water and 120 ft.

Dana's classification of reef-formations is useful in surveying the Hawaiian reefs:

¹ James D. Dana, "Corals and Coral Islands," 1872.

1. *Outer reefs*, or reefs formed from the growth of corals exposed to the open seas. Of this character are all proper barrier reefs, and such fringing reefs as are unprotected by a barrier. All of the larger Hawaiian reefs are of this character.



FIG. 1. Midway Island. A nearly complete circular coral atoll, about 16 miles in circumference; area of lagoon about 38 sq. miles; several low sand islets in the lagoon.

2. *Inner reefs*, or reefs formed in quiet waters between a barrier and the shores of an island. The reefs of this type are very rare in Hawaii; usually they are mere hummocks in the lagoon of the fringing reef.

Kaneohe Bay and Pearl Harbor, on Oahu, are essentially large drowned valley regions, converted by subsidence into land-locked bays, which have become more or less completely barred and filled by coral growths. Were there not such large quantities of fresh, mud-laden water poured into these bays, they would be veritable coral wonderlands, for it is in protected waters of inner channels or lagoons that corals attain their finest development, and the "richest views are presented to the explorer of coral scenery."

The marine flora and fauna in these bays presents

many contrasts with those of the true lagoons and outer reef rims. All of the pure-sea-water-requiring organisms are wholly absent or rare, and in their places one finds a large series of brackish water and silt-loving forms. The generalization is quite accurate for the Kaneohe and Pearl Harbor inner reefs that

The main distinction between the inner and outer reefs consists in the less fragmentary character of the rocks in the former case, the less frequent accumulations of débris on their upper surface, and the more varied features and slopes of the margins. . . . There is to be found about inner reefs, over large areas, solid white limestone, showing internally no evidence of its coral origin, and containing rarely a shell or other imbedded fossil. It is a result of the consolidation of the fine coral sand or mud that is made and accumulated through the action of the light waves that work over the inner reefs. Other portions of reef consist of branching corals, with the intervals filled in by sand and small fragments; for even in the stiller waters fragments are to some extent produced. A rock of this kind is often used for buildings and walls on the island of Oahu. It consists mainly of *Porites*, and in many parts is still cavernous, or but imperfectly cemented.²

3. *Channels or seas* within barriers, which may receive detritus either from the reefs, or from the shores, or from both these sources combined. These channels correspond to the lagoons of the fringing reef, except that the channels are much larger. The Hawaiian lagoons are generally floored with coral sand, indicating that reef erosion is more rapid than coast erosion.

4. *Beaches and beach formations*, produced by coral accumulations on the shore through the action of the sea and winds. Beaches and dunes of coral sand are common on the islands of Molokai, Oahu, Kauai, Laysan, Midway, Ocean, etc.

Of the three great classes of coral reefs—fringing, barrier, and atoll—the first and last only have representation in the Hawaiian Archipelago. The fringing reefs are platforms of coral limestone which extend but a relatively short distance from the shore. The seaward edge of the platform is characteristically somewhat higher than the inner portion, and is usually awash at low tide. The reef

² Dana, *loc. cit.*

is cut by more or less numerous channels, which mark those places where streams flow down from the land. There is usually a lagoon—of sufficient depth to be navigable by canoes or small boats—between the reef rim and the shore. The outer wall of the fringing reef is steep, and in the Hawaiian Islands descends abruptly into deep water. The reef rim is the region of most active coral growth, the shoreward coral being gradually killed by fresh water and the deposition of mud and sand.

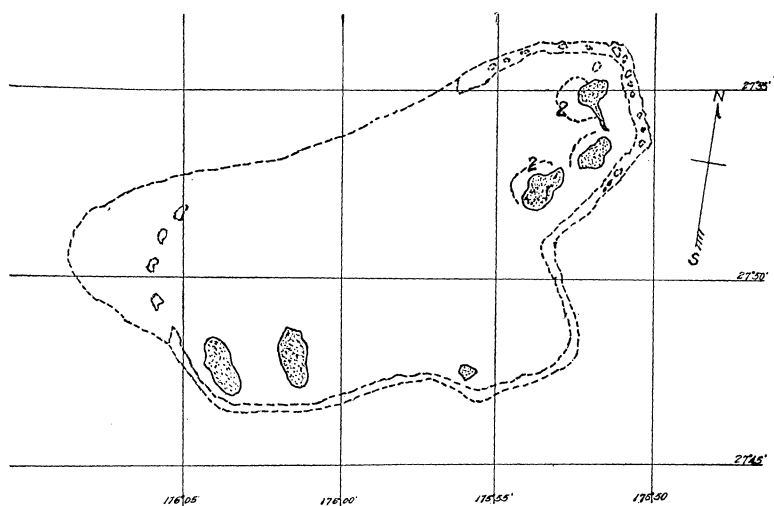


FIG. 2. Pearl and Hermes Reef. An irregular, oval coral atoll, 42 miles in circumference; area of lagoon about 80 sq. miles; numerous low sand islets in the lagoon. The soundings (2) are in fathoms.

Barrier reefs may be considered as fringing reefs upon a large scale. Although rare in the North Pacific Ocean, there are many fine examples in the South Pacific. The grandest in the world is the Great Australian barrier reef, which is 1,250 miles long, and supports a wonderfully rich marine life.

An atoll is an annular or ring-shaped reef, either awash at low tide or surmounted by several islets, or less frequently by a complete circle of dry land surrounding a central lagoon. The outer wall of the atoll generally descends with a very steep but irregular slope to a depth of

3,000 ft. or more. The central lagoon is seldom more than 60 ft. deep, and is often much less. There are usually one or more navigable passages leading from the lagoon to the open sea.

The thickness of the Hawaiian reefs is an engaging subject for speculation. Many of the reefs are undoubtedly several thousand feet thick at their seaward margins. Dana writes:

Could we raise one of these coral-bound islands from the waves, we should find that the reefs stand upon submarine slopes, like massy structures of artificial masonry; some forming a broad flat platform or shelf ranging around the land, and others encircling it like vast ramparts, perhaps a hundred miles or more in circuit.

The late Dr. S. E. Bishop, of Honolulu, estimated the depth of the coral at Barber's Point, Oahu, to be 2,500 ft.

Our first exploration of a Hawaiian coral reef, some ten years ago, made a lasting impression, so novel and vivid were those initiatory experiences. The tropic morning was fine and clear, with the clouds heaped along the mountains, and the seaward sky flawless. The trade winds were unusually quiet and the tide was at lowest ebb. All conditions were most favorable for a detailed examination of the reef. My comrade and I embarked in a native outrigger canoe and paddled from the well-known Waikiki Beach, near Honolulu, to the white surf-lines of the reef-rim. This is one of the richest portions of the Oahu fringing reef, from the biological standpoint. We were clad in bathing suits and provided with suitable collecting apparatus and water-boxes—glass-bottomed boxes by means of which the sunlit translucent waters are easily surveyed.

Arriving at a suitable location, a thousand feet from the shore, where the water was scarcely two feet deep, we anchored the canoe and prepared for wading. We were equipped with old shoes to protect our feet from the coral (which can cause very painful and slow-healing wounds); with broad-rimmed hats to protect eyes, face, and neck from the intense glare of sun and water; with hammers

for breaking up the coral blocks and for loosening material; and with sundry haversacks, wide-mouth bottles, formalin, etc. For three entrancing hours we wandered over the ledges, knolls, and sandy pockets of the reef, bewildered by the luxuriant diversity of marine life. Fantastic clumps of living coral, a large number of strange molluscan species; bright-spotted crabs and other

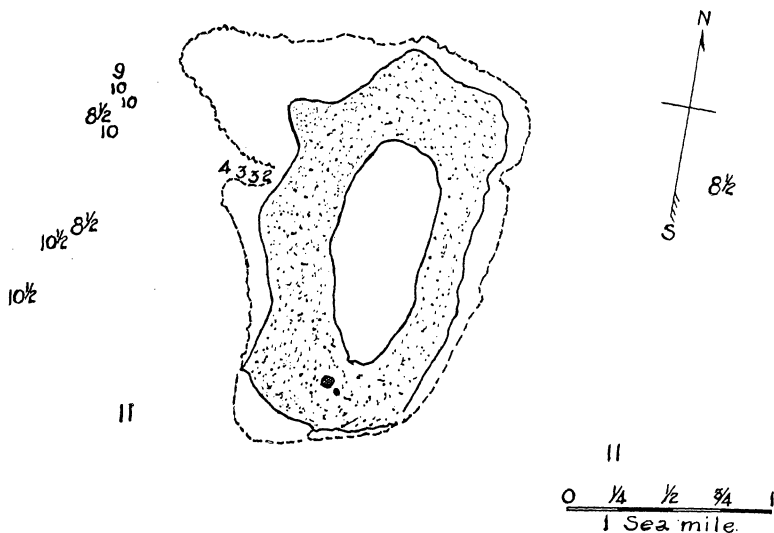


FIG. 3. Laysan Island. An elevated coral island, with a central lagoon. The soundings are in fathoms, as in all the maps. The dotted line indicates the reef rim; this also applies to all the maps.

crustaceans in an array of shapes and sizes; colonies of sea-urchins; spidery-armed brittle-stars; exquisitely beautiful hydroid colonies; bizarre-hued holothurians; and everywhere marine algæ of many tints and shapes, representing a long list of interesting genera. Gorgeously colored fishes, small and large, lurked in the shadowy reef pools, and evaded prolonged inspection. It is impossible to describe the profound impression produced by one's first sight of the strange and fascinating reef-world.

The coral fauna of the Hawaiian reefs, although not as rich nor as diversified as those of more tropical waters, is not to be regarded as scanty. Dr. T. Wayland Vaughan, who thoroughly investigated the *Albatross* and Bishop

Museum collections, reports 15 families, 34 genera, and 123 species, varieties and forms. As Bryan³ states,

Some idea of the richness of the coral fauna of any given locality can be gathered from the fact that the reef and shallow waters along the south side of Oahu, but especially at Waikiki, yielded examples of thirty-four of the species enumerated.

Of the Hawaiian stony corals (Madreporarians) the genus *Porites* is the most abundant and is represented by the largest number of species and varieties. *Pocillopora* ranks next in importance, followed by *Montipora*, *Pavonia*, *Favia*, *Leptastrea*, *Cyphastrea*, and *Fungia*. The last-named genus merits special mention because of the unique shape of the skeleton, which closely resembles the inverted head of a fully expanded mushroom, hence the name mushroom coral. These are solitary, and fairly common. They are usually found lying flat on the floor of little pools or pockets along the outer edge of the reef.

The corals, like many other groups of marine organisms, are remarkable for the variety and brilliancy of their color during life. Those who know only the bleached museum specimens have little conception of the living tints, some of rare delicacy, others of brilliant hue. The Hawaiian reefs, although they do not show colors as striking as those of the South Pacific and Indian Oceans, are not lacking in color, and the "Coral Gardens" are becoming far-famed as tourist attractions. Pink, yellow, green, brown, purple and scarlet are represented in many shades and combinations.

One of the most beautiful of the Hawaiian corals is a highly precinctive species, *Dendrophillia Manni*, which is known only from Kaneohe Bay, on the island of Oahu. The living coral is a rich deep orange red. There are numerous short branches, each of which is surmounted by a single bright orange polyp. When fully expanded the polyp is about three quarters of an inch long, and resembles a miniature sea-anemone. The polyp can withdraw completely within its cup. This species is rare,

³ William Alanson Bryan, "The Natural History of Hawaii," Honolulu, 1915.

occurring only here and there along the margins of the little coral islands in Kaneohe Bay.

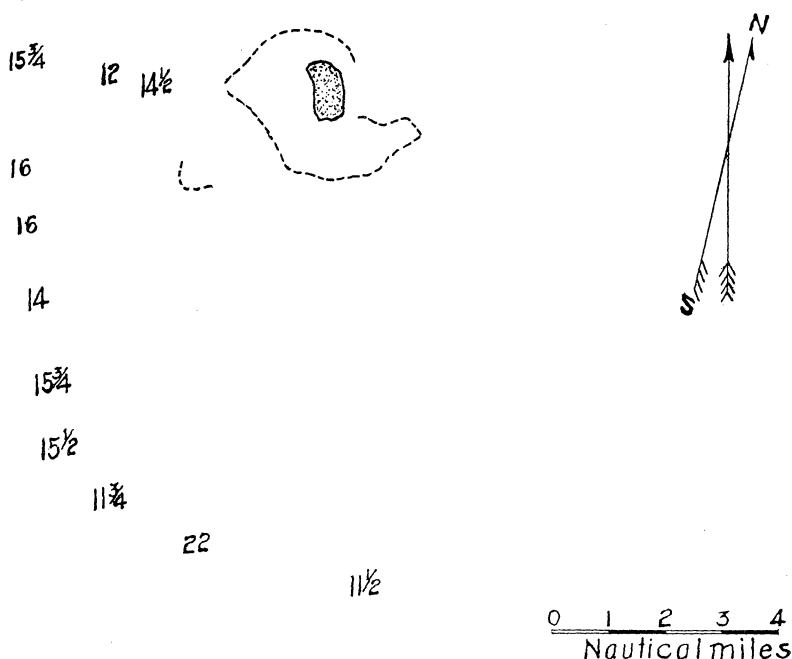


FIG. 4. Lisiansky Island. A low, oval island of coral sand, two miles by three miles; the lagoon empty of water. The surrounding reef extends six or seven miles from the isle.

The famous black coral, *Antipathes abies*, is absent from the Hawaiian reefs, although it has a wide distribution in the Indian and South Pacific Ocean. It grows to considerable size in the tropical waters of the Great Barrier Reef of Australia.

The eight-rayed corals (*Alcyonaria*) are very rare on the reefs, but occur in fair abundance in the deep offshore waters. The *Albatross* collected about 70 new species, 40 of which were new to science. The Red or Precious Coral of commerce, *Corallium rubrum*, does not occur in the Hawaiian Archipelago. It is most abundant in the Mediterranean Sea, although also occurring off the coasts of Ireland and Africa. Related species of slight commercial value have been obtained off Mauritius and near Japan.

The *Alcyonacea*, organ-pipe and blue corals, are represented in Hawaii by only five species; the *Gorgonacea*, sea-fans, by 16 species; and the *Pennatulacea*, sea-pens, by 48 species. Many of the Hawaiian members of these groups are of great beauty, but are never found *in situ* on the reefs, and when rarely washed ashore are badly mutilated by the waves. Some of the species are phosphorescent.

The typical Hawaiian fringing reef exhibits five distinctive biological zones. This zonation parallels the shore-line, and is best developed on those reefs which possess wide lagoons and a well-defined outer margin or rim.

1. *Beach or Inshore Waters*.—The shallow inshore waters, varying in depth from 6 to 36 inches, sustain a number of the quiet-water algæ, such as *Enteromorpha* spp., *Hypnea nidifica*, *Gracilaria*, *Chaetomorpha*, *Ulva*, *Chondria*, *Liagora*, etc. The bottom is of coral sand or mud, more or less contaminated by volcanic soil washed from the lowlands. The water is often mingled with relatively high percentages of fresh water. The nature of the bottom depends largely upon the proximity of fresh-water streams and of the reef-rim. In many places where the surf is heavy and reef material abundant, the bottom is pure white coral sand, with practically no rock or mud. In other districts there are large mud-flats exposed at low tide; the limestone pavement is covered with a thin sheet of mud, with little sand. Every gradation may be found between these two extremes. At the mouths of streams and at numerous other places along the coasts where fresh-water springs exist below tide-level, the inshore water is so fresh as to prohibit the development of the strictly marine species.

2. *Partially Submerged Rocks*.—In some places the beach and shallow waters are devoid of rock masses, but in general one finds partially submerged rocks scattered all along the coasts. These may be either close inshore, in the form of ledges or detached fragments, or may lie

at varying distances from the shore. In any case they distinctly indicate, by their horizontal banding of algal and hydroid life, the ranges of high and low tide. The rocks are either of consolidated reef coral or of black basaltic lava; tufa rocks, and sedimentary coral sandstone are infrequent. Some groups of marine organisms show strong preference for the coral rock, others for the lava rock. The rocks may be in somewhat protected situation or may be exposed to the full force of the surf. The following genera contain algæ which are representative of the kinds that withstand the constant battering of the waves: *Gymnogongrus*, *Codium*, *Haliseris*, *Asparagopsis*, *Dictyota*, *Gelidium*, *Ahnfeldtia*, *Porphyra*. The controlling factor in the alga-flora of the partially submerged rocks seems to be the circulation of pure, well-oxygenated sea water. Rocks in stagnant or impure water support a scanty flora as compared with those of the surf-swept localities.

3. *Pools*.—Beyond the rock litter, although sometimes interspersed by it, lies the zone characterized by numerous pools or pockets. These cup-like depressions in the lagoon floor vary in size from little pockets two or three feet in depth and diameter to large pools twenty or thirty feet in depth and diameter. In wading or paddling over the reef, the pools are easily distinguished by the darker tint of their waters as contrasted with that of the shallow lagoon. These pools in the floor of the lagoon are not to be confused with the tidal pools, that lie along the beaches, and are entirely detached at low tide. The lagoon pools are inhabited by a great variety of algæ and animals that prefer these shadowy havens to the exposure of the shallows or the outer reef. The bottom of the pool may be covered with clear coral sand, or coral débris, or masses of living coral; its alga-flora will depend upon its depth and the resultant intensity of illumination.

The following are typical alga genera that have representatives in the lagoon pools: *Corallina*, *Peysonnelia*, *Grateloupia*, *Ceramium*, *Amansia*, *Polysiphonia*, *Chon-*

dredging is almost impossible, and diving is both laborious and unsatisfactory.

5. *Reef-Rim*.—Upon paddling across the lagoon to the outer rim of the reef, one comes to shallow water, where the heavy combers break and where wading is again possible. This zone is a favorite fishing-ground of the native Hawaiians, as it abounds with plant and animal life. The highest portions of the rim are usually exposed at low tide; at high tide they are covered by 18-24 inches of water. There are many table-rocks or shoals, with deep channelways between. The rim is not regular or symmetrical; there are many indentations, crags, débris slopes, pools, hummocks and sandy spots. Almost all of the visible coral of this region is living coral, associated with an abundance of corallines, bryozoans, hydroids and red and brown algæ. Some of the algal genera that are confined largely to the outer reef-rim are: *Codium*, *Asparagopsis*, *Gymnogongrus*, *Porphyra*, *Turbinaria*, *Dictyota*, *Haliseris*, *Gelidium*, etc. Many of the species that inhabit these turbulent and surf-churned waters are not the tough, cartilaginous forms, but are very delicate and fragile species, that apparently survive the wave action because of their very delicacy. This is particularly true of some of the finer red algæ.⁴

Highly important on the Hawaiian reefs are the coralline or stony algæ or nullipores. A number of genera—

⁴ Some of the representative marine algæ of Hawaii that are common on the coral reefs and shallows are: *Oscillatoria bonnemaisonii*, *Phormidium crosbyanum*, *Lyngbya semiplena*, *L. majuscula*, *Hydrocoleus cantharidosmus*, *Nodularia Hawaiiensis*, *Hormothamnion solutum*, *Scytonema fuliginosum*, *Calothrix eruginea*, *Ulva* spp., *Enteromorpha* spp., *Chaetomorpha pacifica*, *Cladophora* spp., *Bryopsis plumosa*, *Caulerpa taxifolia*, *Halimeda* spp., *Codium* spp., *Valonia* spp., *Dictyosphaeria favulosa*, *Microdictyon umbilicatum*, *Ectocarpus* spp., *Sphacelaria* spp., *Hydroclathrus cancellatus*, *Asperococcus bulbosus*, *Turbinaria ornata*, *Sargassum* spp., *Padina pavonia*, *Dictyota* spp., *Liagora decussata*, *Galaxaura lapidescens*, *Scinaia furcellata*, *Gelidium* spp., *Wrangelia penicillata*, *Gymnogongrus* spp., *Ahufeltia concinna*, *Gracilaria* spp., *Hypnea nidifica*, *H. armata*, *Plocamium sandwicense*, *Martensia flabelliformis*, *Asparagopsis sanfordiana*, *Laurencia* spp., *Chondria tenuissima*, *Polysiphonia* spp., *Amansia glomerata*, *Ceramium* spp., *Grateloupia flicina*, *Peyssonnelia rubra*, *Corallina* spp., *Lithothamnion* spp.

Lithothamnion, *Corallina*, *Mastophora*, and others—are abundant on the reefs, and undoubtedly have been active as reef-builders. The importance of the lime-secreting algæ was overlooked by the earlier students of coral reefs, but is now receiving adequate consideration. Howe⁵ shows that these forms work effectively at greater depths and at lower temperatures than do the true corals, and that they are much more generally and widely distributed than the latter.

The Hawaiian coralline algæ inhabit the shallow waters, as well as occurring at considerable depths. In the former situations they form beautiful rose, purple and lavender incrustations. On the faces of cliffs that are washed by the sea these incrustations appear as conspicuous bands, extending from high-tide mark or the uppermost wash of the surf down to the zone of minimum illumination. The lower margin of the coralline zone has not been investigated in the Hawaiian Islands, but in other island groups they flourish at 1,000 ft. depth. In the coralline zone are also many of the calcareous hydrozoa.

Sponges of many species, sizes and colors abound in all protected portions of the reefs, but have never been made the subject of critical taxonomic study. They range from tiny, fragile forms, the size of a shoe-button, up to coarse horny masses as large as a man's head. The lesser species are common on the coral-rock litter in the lagoons. The larger forms inhabit the deeper waters, and are torn from their anchorage only by the occasional severe storms. After a period of southerly storms, for example, the leeward beaches are littered with these large, tough sponges, which average eight inches in diameter.

The range of color is bizarre and striking. In a single afternoon's collecting one may pick up, in the shallow water, species of bright red, pale yellow, rich purple, dull brown, creamy white, green, and dead black pigmentation. Dredging reveals others which add to the chromatic series. Most of the sponges are of the encrusting type, the body

⁵ M. A. Howe, "Building of Coral Reefs," *Science*, 36: 837-842, 1912.

conforming to the substratum and having no definite shape. The *Calcarea* are not uncommon in the littoral region, especially in sheltered situations among rocks and seaweed. These and the true horny sponges (*Ceratosa*) have not been found below 2,700 ft. The sponges found at the greatest oceanic depths are members of the *Hexactinellida* and *Choristida* of the *Non-Calcareae*.



FIG. 6. Island of Oahu. Showing extensive development of coral reefs // and elevated coral limestone ///. Note the abundance of coral in the vicinity of Pearl Harbor (the fan-shaped bay on the south coast), Kaneohe Bay (on the northeast coast) and along the southern shores.

The Hawaiian sponges have few or no natural enemies, and do not appear to be edible to fishes, crustaceans or molluscs. Innumerable lowly forms, however, inhabit their tissues, for shelter, if not for food. The interior of any one of our common reef sponges is almost sure to be found teeming with minute crustaceans, annelids, molluscs and other invertebrates.

None of the Hawaiian species have been utilized commercially and no serious attempts have been made to in-

introduce and establish the valuable species from other parts of the world. All of the commercial sponges belong to the two genera *Euspongia* and *Hippospongia*, which do not occur on the Hawaiian reefs. Such an enterprise, if undertaken with thorough scientific supervision, would unquestionably meet with success. There are many areas along our reefs where the sponges could be established. With adequate labor and marketing arrangements a steady development of the industry would be assured.

It is of interest to note that of the fresh-water sponges, *Spongillinae*, a group which is widely distributed in all parts of the world, no representatives have been taken in the Hawaiian Islands.

Jellyfish are of casual occurrence along our reefs. The smaller forms are chiefly Hydrozoan medusæ; the larger ones are Scyphozoans. A relatively few species are known and the life-cycles of these are not known in detail. A number of the tiny species are phosphorescent, and on clear nights when the sea is calm and other conditions are favorable, they give beautiful luminous effects. In paddling along the reef in an outrigger canoe, on such a night, the paddles, at every stroke, drip with tiny stars. Many of the larger species have gonads, tentacles, radial canals, or other organs brilliantly pigmented.

The large forms attain diameters of 8–12 in. and sometimes appear in great numbers in quiet, protected waters. Pearl Harbor, for example, which is almost wholly landlocked, is a favorite habitat. At low tide, in other parts of the islands, along the coral beaches one sometimes finds great numbers of jellyfish stranded and slowly deliquescing.

In addition to the true jellyfish the reefs support a rich hydrozoan or marine hydroid fauna. The littoral species have not been studied taxonomically; the *Albatross* collections were made at depths of 60–3,000 ft. These latter comprised 49 species, representing 27 genera and 11 families. The shallow-water zoophytes or hydroids are abun-

dant in all protected situations; many forms also inhabit the surf-beaten rim. *Sertularia*, *Plumularia* and *Campanularia* are well-known genera. The species are all of small size and superficially resemble in habit, color and habitat the more delicate marine algæ.

The false corallines or *Hydrocorallinæ* are also very abundant and have played an important rôle, as have the coralline algæ, in the construction of the Hawaiian reefs. These colonial animals resemble delicately branching corals; their bleached and rather fragile skeletons are common on the beaches. When alive the corallines are of various tints of pink, orange and salmon, and add bright touches of color to the brilliant ensemble of the reef. The *Hydrocorallinæ* occur only in tropical seas; *Millepora* and *Stylaster* are typical genera.

That remarkable order of free-floating colonial hydroids, the *Siphonophora*, is well represented in all tropical waters, and has numerous forms in the Hawaiian marine fauna. This group exhibits the greatest diversity of form. The common "Portugese man-of-war," *Physalia utriculua*, with its brilliant peacock-blue float and long retractile tentacles, is abundant along the reefs and shallows, and like the jellyfish, is often cast ashore in enormous numbers. The tentacles contain powerful batteries of stinging capsules; the wounds are intensely painful, and so this lovely evanescent creature is dreaded by bathers. Other well-known genera are *Halistemma*, *Diphyes*, *Porpita* and *Vellelo*. *Porpita pacifica*, the sea-money, is a beautiful blue-fringed disc about $1\frac{1}{2}$ in. in diameter. *Vellela pacifica* is also abundant at certain seasons. It resembles *Physalia*, but has much shorter tentacles.

Sea-anemones, *Actiniaria*, are abundant along the Hawaiian reefs, but no taxonomic studies have been made. A number of species inhabit the inshore pools whose waters are periodically renewed by waves or tides; others may be found on the floor of the lagoon, and still others on the protected sides of rocks which stand in the heavy

surf. The colors most frequently observed are shades of tan, olive and purple; some forms have tentacles which are beautifully pigmented. The size varied from species so minute as to almost escape detection up to fine showy forms 1-2 in. in diameter. They form considerable colonies, sometimes covering areas of several square feet. Isolated individuals, particularly of the larger species, are not rare. Usually their rosette of tentacles and brilliant color renders them quite conspicuous, but many kinds are embedded more or less completely in the substratum, and upon the slightest alarm contract into shapeless lumps, and are thus easily overlooked.



FIG. 7. Coral Reefs near Honolulu, Oahu. The city of Honolulu is built upon a limestone plain. The coral reefs which extend along the coast are well developed and very rich in plant and animal life. There are numerous evidences of repeated subsidence and elevation. The crater on the right is Diamond Head (Leahi); the channel to the left is Kalihi Channel. Honolulu Harbor is the middle channel.

The *Ctenophora* have about 20 known species in Hawaiian waters, but these are so rare and fragile that they are practically unknown to the reef-collector. They are all pelagic, delicate, transparent creatures, with long tentacles and peculiar comb-like locomotor organs. As they swim gently through the sunlit waters their transparent bodies and tentacles yield beautiful iridescent reflections. *Hormiphora*, *Cestus*, and *Beroë* are well-known genera. All the members of this highly specialized group are solitary and do not form skeletons.

The fauna which inhabits the innumerable small cavities in the coral, and which drills countless tunnels through the soft rock, is of much interest. This fauna comprises chiefly the worm-like animals or sea-worms. Important groups are *Turbellaria*, *Nemertinea*, and *Annelids*. Some species creep about in the interstices; others construct covered passageways on the surface of the coral. Others burrow in the sand and mud on the floor of the lagoon. Some tunnel deviously through the coral rock itself. Many of the sea-worms are brightly colored. Little is known concerning the relationships or life-histories of the Hawaiian forms. *Nereis*, *Serpula*, *Terebella*, *Tubifex*, *Sipunculus*, and *Echiurus* are characteristic annelid genera.

The true corallines (*Polyzoa*) or sea-mats bear a close resemblance to the hydroid zoophytes, and only upon microscopic inspection show that their organization is much higher than that of the hydroids. The skeleton is not exclusively calcareous; in many forms it is chitinous or even gelatinous. These corallines are abundant on the Hawaiian reefs.

The true starfishes, *Asterioidea*, are comparatively rare on the reefs themselves, although fairly common in the offshore waters. The brittle-stars, *Ophiuridea*, are the common reef forms, and lurk in every cranny. The *Albatross* expedition collected 60 Hawaiian species of true starfish during its dredging operations in the island channels; they were taken at depths of 60-6,000 ft. These represented 46 genera and 20 families; 52 species were new to science. According to Bryan,

Large specimens of an eight-rayed starfish, *Luidia hystrix*, are occasionally captured at Pearl Harbor. They are often a foot and a half in diameter. A similar but very small species is to be found abundantly in the coarse green sponges in Kalihi Bay and at Pearl Harbor. A small, stiff, irregularly developed, pink, leather-like species, *Linckia* sp. without spines, is occasionally found crowded into small holes in the coral reef.

The common brittle-star, *Phicema* sp., is blue-black in color, with small body and long snaky arms. It is gre-

gamous in habit, and the collector frequently finds a dozen or more congregated beneath a half-buried stone or coral mass. A tiny pink species, *Ophiothrix* sp., with remarkably long arms, inhabits crevices in the coral. It is very difficult to capture intact, because it, like most of the Ophiuroids, possesses to a remarkable degree the faculty of self-mutilation. Many of the Hawaiian brittle-stars, when disturbed or removed from the water, sever portions of their arms piece by piece until finally nothing is left but the central disc. This is capable of developing a new set of arms; and a detached arm can, under favorable conditions, develop a new disc and a completed series of arms. The basket-stars, *Cladiophiura*, have never been collected on the Hawaiian reefs.

The sea-urchins, *Echinoidea*, are richly represented, but most of the species inhabit the deep offshore waters. The inshore species are gregarious and common in all rocky situations along the coasts, as well as on the reefs themselves. *Podophora pedifera*, for example, prefers the black lava rocks and cliffs exposed to the full force of the surf, and is so abundant that the zone of massive basalt which it inhabits is literally honeycombed with its burrows. Several species of *Echinometra* are also very abundant; these prefer the shallow waters of the lagoons. In the deep holes and caverns along the outer edge of the reef is a large purple-black species, *Diadema paucispinum*, with slender, awl-shaped spines. In the same situations occurs *Echinothrix desori*, a large form whose long spines are beautifully banded with gray and black. The curious club-spined urchins, *Heterocentrotus* spp., occur here and there along the reef, and are frequently exhibited in the Honolulu Aquarium. The sea-biscuit, *Brissus carinatus*, is a large, heart-shaped urchin, covered with short, brown hair-like spines, and is occasionally found along the reef rim. A number of the Hawaiian urchins are known to the natives as *wana*, or "sea-eggs," and are habitually used by them for food. They may be purchased in the local fish markets.

Numerous species of holothurians (known as sea-cucumbers, sea-squirts, and *bêche-de-mer*) are common in the shallow waters. There are over 40 described species, representing 4 families and 21 genera. A large, worm-like form, *Opheodesoma spectabilis*, is common at Pearl Harbor and Kaneohe Bay, in quiet water. It is about 2 ft. long and $1\frac{1}{2}$ inch diameter, reddish brown mottled with brown. A large, dark greenish-brown species, *Stichopus tropicalis*, is plentiful in the large pools of the outer reef, near Honolulu. Inhabiting the tidal pools in the lava rocks is another large form, *Holothuria atra*; dark brown, and with ambulacral feet scattered all over its body. Frequently associated with it is a heliotrope-purple species, *Holothuria cinerascens*. There are about 600 known species of holothurians, varying in size from $\frac{1}{2}$ inch to 2 or 3 feet. They are found in all seas, but are particularly abundant in the West Indies, and between Asia and Australia. They feed chiefly on Foraminifera. The movements of all the Hawaiian species are very sluggish; they seem to have few enemies. All are harmless, although of unpleasant aspect. They are capable of the most extraordinary regeneration of parts, even of the most important organs. Many species show the curious habit of evisceration—when alarmed they dispel from the anal opening the viscera either wholly or in part. In the course of a few weeks all of the lost organs are replaced by a new set.

The Crinoids or sea-lilies do not exist in the shallow waters of the Hawaiian reefs. A dozen forms were collected by the *Albatross* at depths of about 600 ft. These all proved to be new species, although representing 8 wide-ranging genera in 4 families of the non-stalked *Neo-Crinoidea*. Crinoidal fossils have not been found in the uplifted coral limestone beds of the Hawaiian Archipelago. These forms made important contributions to the Silurian and Devonian rock strata in other parts of the world, during which epochs the crinoids were enormously abundant.

Molluscs abound on all the reefs. There is a tremendous range of size, structure, habitat and generic representation. The marine molluscan fauna has never received adequate attention, as scientific interest has centered upon the unique terrestrial and arboreal forms. There are about 20 species of bivalves (*Pelecypoda*) that are fairly common. These include such genera as *Mytilus*, *Perna*, *Arca*, *Ostrea*, *Anomia*, *Pecten*, *Tellina*, *Cadokia*, *Cytherea*, *Venus*, *Cardium* and *Chama*. *Tellina sugosa*, the *Olepe*, is, according to Bryan, "the most important shell-bearing mollusc" in the islands. The famous pearl shell, *Avicula margaritifera*, of the South Pacific, does not occur in Hawaiian waters. The Hawaiian pearl oyster, *pa*, *Margaritifera fimbriata*, has a shell often 3 or 4 inches broad, with a brilliant iridescent interior. It is the species which gave Pearl Harbor its name. In the early days the collecting of *pa* was a royal monopoly, like the collecting of sandalwood. The pearl-shell was used by the Hawaiians chiefly for making fish-hooks, and for the curious shell-eyes of their wooden gods. A true pearl-bearing species also occurs at Pearl Harbor and other localities in the group in the deeper offshore waters. The edible oysters are represented by *Ostrea rosea*, which is not of sufficient abundance to permit commercial exploitation.

The chitons and their allies, *Amphineura*, are uncommon in the shallows, but a thorough systematic survey would undoubtedly bring to light many additional forms. The true chitons, *Placophora*, are confined largely to the shallows, and apparently are herbivorous, feeding on minute algæ and diatoms. The *Aplacophora* as worm-like, shell-less creatures, with the body beset with calcareous spicules. They are wholly absent from the littoral zone, occurring only at considerable depths—3,000 ft. and in some instances down to 7,500 ft. They are carnivorous and subsist on such small animals as hydroids and coral polyps.

The univalves or Gasteropods are by far the most

abundant molluscs on the Hawaiian reefs and aggregate several hundred species. Space forbids any detailed treatment of this huge and highly diversified class. A bare enumeration of important and common families and genera, adapted from Bryan, will indicate the richness of the marine univalve fauna (the number of species is in each instance an approximation):

Family	Species	Typical Genera
Tritons; Tritonidæ	12	<i>Triton</i> , <i>Ranella</i> .
Spiny Rock Shells; Muricidæ . .	30	<i>Purpura</i> , <i>Ricinuia</i> , <i>Vexilla</i> , <i>Sistrum</i> .
Spindle Shells; Fusidæ	6	<i>Fusus</i> , <i>Latirus</i> , <i>Peristernia</i> .
Whelks; Buccinidæ	6	<i>Pisania</i> , <i>Cantharus</i> .
Dog Whelks; Nassidæ	4	<i>Nassa</i> .
Mitre Shells; Mitridæ	26	<i>Mitra</i> , <i>Imbricaria</i> , <i>Turricula</i> .
Margin Shells; Marginellidæ . .	4	<i>Erato</i> , <i>Marginella</i> .
Olive Shells; Olividæ	4	<i>Harpa</i> , <i>Olivæ</i> .
Dove Shells; Columbelloidæ . . .	15	<i>Columbella</i> , <i>Engina</i> .
Cone Shells; Conidæ	25	<i>Conus</i> .
Auger Shells; Terebridæ	25	<i>Terebra</i> .
Conch Shells; Strombidæ	9	<i>Strombus</i> .
Cowry Shells; Cypræidæ	40	<i>Cypræa</i> , <i>Trivia</i> .
Tun Shells; Doliidæ	2	<i>Dolium</i> .
Cameo Shells; Cassisæ	5	<i>Cassis</i> .
Moon Shells; Naticidæ	10	<i>Natica</i> .
Slipper Shells; Calyptræidæ . . .	12	<i>Crepidula</i> , <i>Crucibulum</i> , <i>Hipponyx</i> .
Eulimas; Eulimidæ	17	<i>Eulina</i> .
Pyramid Shells; Pyramidellidæ .	3	<i>Pyramidella</i> .
Sun-dial Shells; Solariidæ	6	<i>Solarium</i> .
Violet Snails; Ianthinidæ	3	<i>Ianthina</i> .
Ladder Shells; Sculariidæ	10	<i>Scalaria</i> .
Herald's-horn Shells; Cerithiidæ	20	<i>Cerithium</i> .
Periwinkles; Littorinidæ	3	<i>Littorina</i> , <i>Modulus</i> , <i>Risella</i> .
Sea-Snails; Neritidæ	10	<i>Nerita</i> , <i>Neritina</i> .
Turban Shells; Turbinidæ	18	<i>Turbo</i> , <i>Phasianella</i> , <i>Astralium</i> .
Top Shells; Trochidæ	12	<i>Trochus</i> .
Limpets; Fissurellidæ and Patel- lidæ	10	<i>Helcioniscus</i> .
Sea Slugs; Nudibranchiata . . .	10	<i>Aplysia</i> .

The highest and most highly specialized class of molluscs, the Cephalopods, have an abundant and familiar representative on our reefs, in the form of the common octopus or *he'e*. This is popularly called "squid" although it is a true cuttlefish, with a small round sac-like body and eight arms. It is very common in holes and

pools on the rocky platform of the reef, and in caverns along the reef-rim. During the day it hides in cavities; at night it creeps about over the rocks of the bottom. The natives are very fond of the flesh, which they prepare for food in a variety of forms. Dried "squid" is common in the fish-markets. Our cuttlefish is rarely more than 18-26 inches in length. The true "devil-fish" of many a sea-tale is a giant squid, *Architeuthis*, which inhabits the Newfoundland banks and often attains the gigantic proportions of an over-all length of 50 ft., with a body 6 by 9 ft., and enormous arms 40 ft. long.

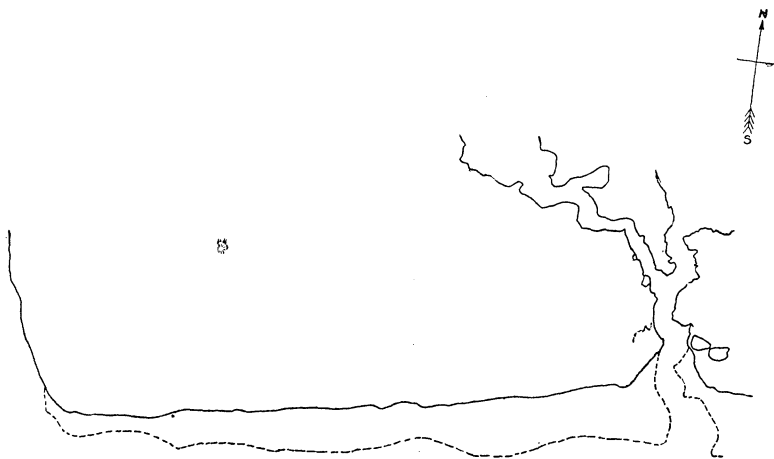


FIG. 8. Coral Reefs near Pearl Harbor, Oahu. The inlet to Pearl Harbor is shown to the right. To the left is the southwest point (Barber's Point) of the island. The lowland is a plain of coral limestone; the reef is rich in biological material.

Our reefs support a characteristic crustacean fauna. In the growing coral at the reef-edge are found a number of small Cyclometopous crabs, which are often beautifully sculptured and colored to harmonize with the coral. The *Alpheidae*, which are shrimp-like *Macrura* with highly asymmetrical claws, are commonly found in pools on the reef. In the coral rubble formed by the disintegration of the reef-rim, in relatively shallow water, numerous Leucosiid crabs are found. Many lowly forms of Entomostraca are abundant, but have never been surveyed

taxonomically. The Phyllopods, Ostracods and Copepods are all plentiful. The Cirripedia include the most aberrant of the crustaceans, and are represented by the common barnacles, including both the stalked (*Lepadidæ*) or goose barnacles, and the sessile (*Balanidæ*) or acorn-

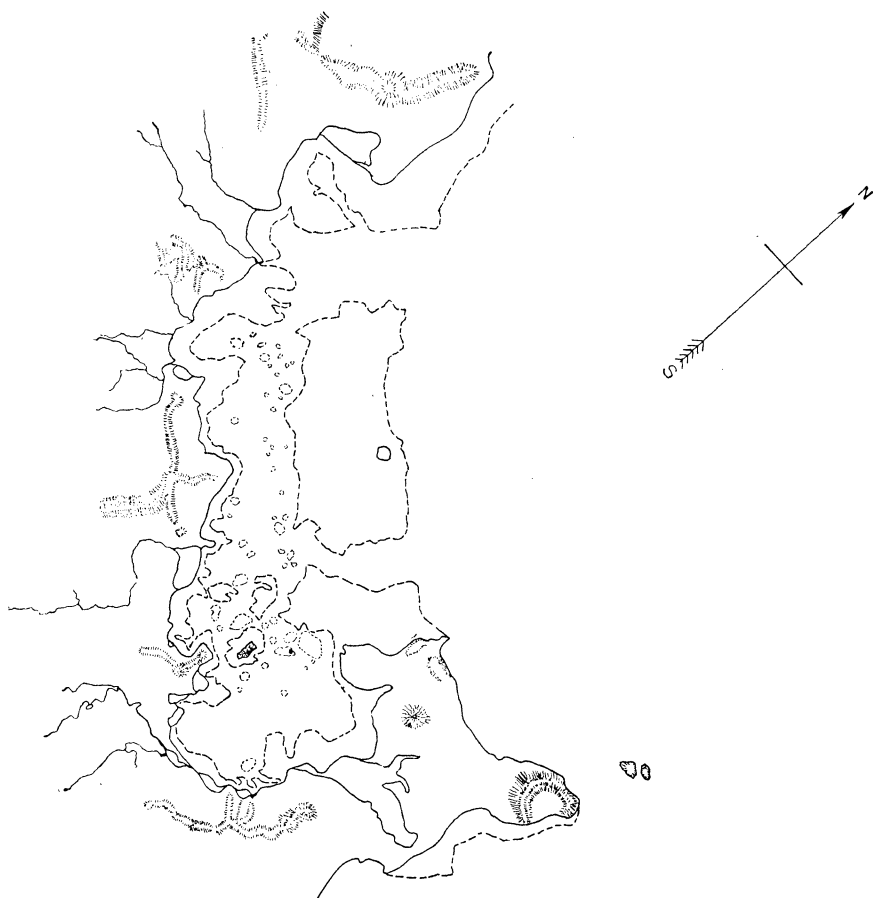


FIG. 9. Kaneohe Bay, Oahu. This bay, which is a drowned valley complex, has a great variety of coral formations. There are many small coral isles and atolls; some are of notable perfection. The exact boundaries of the outer reefs are not known. The crater and little isles to the lower right are secondary volcanic products.

shells. The latter are exceedingly abundant along the shores and reefs; there are also numerous deep-water barnacles.

The most commonly known, the largest and the most highly organized crustaceans, the Malacostraca, are very common. Space does not permit even a general sketch of the many crabs, prawns, crayfish and other interesting forms that teem in the Hawaiian littoral. The so-called Hawaiian "lobster," *ula*, *Panulirus japonicus*, is really a large marine crayfish, and not closely related to the true lobster. It is brilliantly colored and ornamented, with spiny carapace and long antennæ. The *ula* is common in the fish markets, as are also species of *Scyllarides*, *Ocypoda*, and many crabs. Hermit crabs (*Onomura*) are common and in great variety. They make their homes in empty sea-shells, and have many interesting habits.⁶

The last great division of the reef fauna comprises the fishes, a group that could easily occupy the space of an extended monograph. There are several hundred reef species, occupying a wide range of habitats, and varying in size from minute species up to huge food-fish weighing a hundred pounds each. Like the fish of many tropical waters, the Hawaiian species are famous for their brilliant coloration, fantastic patterns, and strange shapes. Many are grotesque; many are exceedingly beautiful; many are consummate embodiment of that riot of gorgeous color that is so characteristic of the reef and its life. The reef fishes, like the other littoral forms of life, were an important item in the dietary of the primitive Hawaiians, and continue so to the present day. Most of the common species are offered for sale in the fish-markets. Space is not available for any detailed account of the in-

⁶ The following list of common littoral and reef species and genera of malacostraceans will indicate the richness of this portion of Hawaii's remarkable reef fauna: I. Brachyura—*Ocypode ceratophthalma*, *O. levis*, *Grapsus grapsus*, *Metopograpsus messor*, *Pachygrapsus plicatus*, *Cyclograpsus*, *Percnon*, *Carpilius*, *Platypodia*, *Lophozozymus*, *Xantho*, *Leptodius*, *Xanthodius*, *Etisus*, *Actæa*, *Chlorodiella*, *Phymodius*, *Grapsillus ferrugineus*, *Polydectus cupulifer*, *Portunus*, *Charybdis*, *Thalamita*, *Podophthalmus*, *Simocarcinus simplex*, *Calappa*; II. Macrura—*Scyllarides*, *Patemonella*, *Parribacus*, *Panulirus*, *Stenopus*, *Pencæus*, *Hippolysmata*, *Spirontocaris*,

shore⁷ fishes, as contrasted with the pelagic and abyssal species.

⁷ Some of the more important groups and species may be listed as follows:

- Sharks *Carcharias melanopterus*; *C. nesiotus*; *Sphyrna zygaena*; *Isuropsis glauca*.
- Rays *Stoasodon narinari*.
- Tarpons *Elops saurus*.
- Bonefishes *Albula vulpes*.
- Milkfishes *Chanos chanos*.
- Anchovies *Anchovia purpurea*.
- Lizardfishes *Trachinocephalus myops*; *Synodus varius*; *Saurida gracilis*.
- Conger Eels *Leptocephalus marginatus*.
- Morays *Muraena*, *Enchelynassa*, *Gymnothorax*, *Eurymyetera*, *Echidna*, *Uropterygius*, *Scuticaria*.
- Trumpetfishes *Aulostomus valentini*.
- Cornetfishes *Fistularia petimba*.
- Needlefishes *Athlennes hians*.
- Half-beaks *Hemiramphus depauperatus*; *Euleptorhamphus longirostris*.
- Flyingfishes *Paraxocetus brachypterus*; *Cypsilurus simus*; *C. bahiensis*.
- Friars *Atherina insularum*.
- Mulletts *Mugil cephalus*.
- Barracudas *Sphyræna helleri*.
- Threadfins *Polydactylus sexfilis*.
- Squirrelfishes *Holotrachys lima*; *Myripristis* spp.; *Flammeo samarra*; *F. scythrops*; *Holocentrus* spp.
- Big-eyed Seads *Trachurops crumenophthalma*; *Carangus*.
- Threadfishes *Alectis ciliaris*.
- Cardinalfishes *Mionorus*, *Foa*, *Amia*.
- Groupers *Epinephelus quernus*.
- Catalufas *Priacanthus*.
- Snappers *Apsilus*, *Aphareus*, *Bowersia*, *Aprion*, *Etelis*.
- Porgies *Monotaxis grandiculis*.
- Rudderfishes *Kyphosus*.
- Surmulletts *Mulloides*.
- Goatfishes *Pseudupeneus*; *Upeneus*.
- Demoiselles *Dascyllus*; *Chromis*; *Pomacentrus*; *Abudefduf*.
- Wrassefishes *Lepidaplois*; *Stethojulis*; *Halichoeres*; *Gomphosus*; *Anampses*; *Thalassoma*; *Julis*; *Coris*; *Cheilio*; *Cheilinus*; *Novaculichthys*; *Iniistius*; *Hemipteronotus*; *Xyrichtys*.
- Scarids *Calotomus*; *Callyodon*.
- Butterflyfishes *Forcipiger*; *Chetodon*; *Holocanthus*.
- Moorish Idols *Zanclus canescens*.
- Surgeonfishes *Hepatus*, *Zebrasoma*, *Ctenochætus*, *Acanthurus*, *Calli-
canthus*.

The gorgeous colors of many of our reef fishes are very evanescent, and undergo rapid deterioration when the fish is taken from the water. Hence the coloration of those offered for sale in the markets often conveys but little idea of their living hues. Preserved specimens and printed descriptions are of even less value.

In concluding this condensed sketch of the Hawaiian reefs, the writer desires to emphasize his impression of the struggle for life which goes on there unceasingly. The reef is a region of intense competition. It is comparable in many of its ecologic relations to the montane rain-forest. The excessive illumination of the reef is perhaps as constraining an influence as is the excessive humidity of the rain-forest. The diversity of organisms which inhabit the reef is far greater than that of any other island habitat. The competition for food is keen and unremittent.

The reef as a food supply for human beings has been a dominant factor in the lives of the primitive Polynesians. Through the experiences of thousands of years they have acquired a very intimate knowledge of the reef and its life, but this has never been given adequate scientific investigation. One of the great forward steps in the economic history of the world will be the scientific utilization of coral reefs and their products.

Triggerfishes *Balistes*, *Balistapus*, *Stephanolepis*.

Puffers *Tetraodon*, *Canthigaster*.

Trunkfishes *Ostracion*, *Lactonia*.

Cirrhitoid fishes *Paracirrhites*, *Cirrhites*.

Mail-cheeked fishes .. *Caracanthus*.

Scorpenids *Sebastapistes*, *Sebastopsis*, *Scorpenopsis*.

Gobies *Eleotris sandwicensis*, *Asterropteryx semipunctatus*,
Eviota epiphanus, *Gobiomorphus eugenius*, *Mapo fuscus*,
Gobiichthys, *Gnatholepis knighti*.

Blennies *Enneapterygius atriceps*, *Alticus*, *Enchelyurus*, *Salaria*s.